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EVOLUTION IN THE PLANT KINGDOM.[1]

BY JOHN M. COULTER.

PERHAPS I should apologize for selecting a subject that has anything to do with so hackneyed a theme as evolution; but you will discover that I intend neither to explain nor defend it. In this presence neither should be necessary. The purpose is to give an illustration of evolution from the plant kingdom, chiefly because illustrations of this law are commonly taken from the animal kingdom, and also because the case among plants is even more striking. One who staggers at the evolution of the horse can find among plants such interminable intergrading that fixity of species becomes a dream of the past, when they were arranged like puppets that popped up in their places when called for, always looked just alike, and were perfectly expressionless. Zoologists are fortunate in having as their stock-in-trade forms of life in which man is specially interested, both as an acquaintance and a kinsman. The public that listens with pricked-up ears and discusses endlessly concerning the evolution of birds, mammals and man, and thus brings a certain popularity to zoology, cares not a straw for the wonderful structures of Gymnosperms and Lycopods, although furnishing irresistible arguments in favor of a theory that has revolutionized scientific thought. One sort of compensation has been that botanists have been considered a sort of harmless folk, while zoologists are "infidel," or "progressive," apostles of darkness or of light, according to the standpoint of the speaker.

Botanical work has been no less effective and advanced in these latter days; but it lacks that possibility of spectacular display which would keep it in the mouth of the public. Monkeys and men the public wants to know about, but Pteridophytes and Phanerogams are decidedly prosy.

It will be found, however, upon a fair examination, that Botany and Zoology are so mutually dependent and helpful that one cannot advance without the other, and the thoughts of both upon such a great question as evolution are practically the same.

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[1] Presidential Address before the Indiana Academy of Science, December 28, 1887.

Turning aside, therefore, from the broad and much-travelled highway which leads from the Moners to Man, we will strike into a by-path, which extends from Protococcus to Phanerogam, and point out a few of its most salient features. Zoologists should be interested in noting how the same ideas have been worked out in the into great kingdoms, and all should remark the wonderful unity of purpose pervading the whole domain of life.

I shall make no attempt to outline a great scheme into which every plant, however formed, shall fitly fall. If I were younger or less acquainted with botany, I could do this; for a young botanist usually begins by attempting to remodel all existing schemes of classification, just as a young college graduate can put veteran statesmen to shame. Botanists have no family-tree arrangement for plants, and will not attempt the construction of one until they know more about the life-histories of the lower groups and more about structure in all the groups. As Dr. Farlow said, in his Vice-Presidential address before the last meeting of the American Association for the Advancement of Science: "On abstract grounds alone, I presume that few botanists would object to the statement that all plants have developed from simple ancestral forms which were nearly related to some of the lower animals. But when it comes to saying in anything like a definite way that certain existing forms have arisen from other lower existing forms or their immediate allies in some past epoch, and so on, until the lowest form is reached, botanists may well insist that imagination should not be allowed too large a scope in supplying missing links. It is precisely in this point that zoologists have an advantage over botanists. The palæontological record of lower animals is more complete than that of lower plants, so that where the zoologist might reasonably form an hypothesis the botanist must rely more on his imagination, until in the end he finds himself in the possession of a chain composed, to a considerable extent, of missing links. As it is, if we would consider the evolution of plants, not getting much light on the progress of the lower forms from palæontology, we are compelled to trust largely to plants as we now find them, and to ask what are the inferences we are permitted to draw from existing structures and conditions."

Not so very long ago it was thought that at least one fact in classification was impregnable, viz., that there were two great and very distinct groups of plants, called Phanerogams and Cryptogams. These two were set off against each other as antipodal groups, between which there was nothing in common. Unfortunately, the names given to these groups were simply an expression of the botanical knowledge of the time. "Apparent reproduction" and "hidden reproduction" may have correctly expressed the facts with respect to these two groups once; but they are very far from doing so now. The modern botanist, with his more complete appliances and methods, has begun to resolve the great nebulous mass of Cryptogams, and has discovered in it distinct systems and groups. The whole subject of Cryptogamic classification is, of necessity, quite inchoate. Certain groups and relationships have been distinctly defined; but among them and around them there float numerous hazy forms that refuse to be classified. Our knowledge is not sufficient to attempt the work with any degree of certainty, but certain broad principles have been struck out which will serve to guide.

It is known now that Phanerogams form but one of several correlative groups. The most useful scheme of classification at present makes the number seven. These seven primary groups must be considered merely as convenient pigeon-holes in which to distribute our facts.

It is not my purpose to go into the details of any supposed order of evolution of the plant kingdom, but to give some general thoughts concerning it and to trace through the development of a single structure. Generalization is always easier than details; for in it one is never embarrassed by the facts.

It seems probable that the plant kingdom must have begun in some such form as Protococcus, the common green slime found staining foundation stones, bark, etc. It surely represents the unit of structure and of function in the vegetable kingdom. We can conceive of no simpler plant-form than a single chlorophyll-bearing cell. Some of you will recall the fact that we have unicellular plants without chlorophyll, such as yeast and bacterial forms; as well as forms called plants that seem to be mostly naked protoplasm, such as slime moulds; but the former probably represent degraded forms, while the animal or plant character of the latter remains in doubt. At any rate, they probably have a far greater complexity than was formerly supposed. We have thus come to consider protococcoid forms as our foundation-stones in rearing the structure of the plant kingdom. Through all the Thallophytes (representing the four lowest of our seven primary groups) there run two parallel lines, the typical or normal plants, containing chlorophyll; and the degraded plants, which are destitute of chlorophyll. This distinction is a very deep-seated one in the plant kingdom, for chlorophyll-bearing plants alone can do normal plant work, viz., the conversion of inorganic to organic material through the agency of chlorophyll and sunlight. Plants without chlorophyll must live as parasites or saphrophytes, a degraded habit which leads to degraded structure. The former in the first four groups, are called Algæ, the latter Fungi. The general opinion, brought out clearly in the address of Dr. Farlow, already referred to, is that Fungi are degraded representatives of Algæ—relatives in reduced circumstances, whose lazy habits of parasitism have entailed upon them degenerate bodies. Just what Fungi have descended from what Algæ it is perhaps impossible to say. The chances are that some of our important Fungi are degraded representatives of algal forms which no longer exist. Specific statement with regard to this relationship is little better than guessing; but the general proposition seems to be fairly well established. We have advanced, then, thus far: that of the two parallel lines, Algæ and Fungi, which run through the four lowest plant groups, the plant kingdom is to be considered as having advanced in the line of the Algæ, the chlorophyll-bearing line; while the Fungi are simply so many degraded forms, which lie strewn along this line of general progress, like drift wood stranded along the banks of a stream. For our purpose, then, the Fungi are to be dismissed, their probable origin having been sufficiently indicated. Starting, then, with protococcoid forms, advancing along the lines of Algæ, and into the chlorophyll-bearing members of the groups above, what notions of evolution can be obtained? Examining our present schemes of classification it will be discovered that chief stress is laid upon the methods of sexual reproduction. It is, as yet, the best thread upon which our facts can be strung, and it usually expresses so thoroughly the highest effort on the part of the plant, that as it advances from simplicity to extreme complexity it seems but fair to consider it a good index of relative rank. I intend to give in merest outline the development of sexual reproduction, guarding such an attempt with the following statements:—

1. This is taken as but a single striking line of development, and must be understood to be accompanied by many other details in asexual reproduction and vegetative structure which bear it out but which we have no occasion to mention. Just as in describing the evolution of the horse the toes are seized upon as the one among other structures most striking and most simple of presentation.

2. There are hosts of side issues which represent departures greater or less from this general line of advance, and which cannot be taken into account in this general sketch. In general, they can be all explained by the law of adaptation.

3. Even the line I propose to follow can be but imperfectly presented; as there is not knowledge sufficient to make it as complete as we would like it, and not time enough to present it as complete as we know it.

Taking, therefore, this thread of sexual reproduction as a guide through the labyrinth of plant forms, we may come to some glimmer of light.

Naturally, the lowest group would contain those plants in which no sexual reproduction has been discovered. In recognition of this position, as well as their probable position in point of time, they have been called Protophytes, or "first plants." The lowly character of lacking sexual reproduction is further borne out in their structure, for they are mostly one-celled forms. In this group stands Protococcus as a type, a single-celled chlorophyll-bearing plant with no discovered sexual reproduction; and, as degenerate representatives, the bacteria and yeasts. You will notice, however, that the definition of this group, on the basis we have adopted, is a negative one, being not as much what we have found, as what we have not found. It follows that this group furnishes a kind of limbo to which all one-celled plants are consigned, in case no sexual reproduction is found, a sort of unresolved nebulous mass, in fact, a cloak for ignorance. It is like the man who undertook a great scheme of classification, and made his two principal divisions "things that I know" and "things that I don't know." The first group he could classify reasonably well; the second he did not have to classify.

In this lowest chamber of Protophytes, every now and then the garment of sexual reproduction is discovered, and its wearer invited to take a place in some upper chamber. But the chances are that the chamber will never be completely emptied, and that there will always be some plants called Protophytes.

In the second group we would expect to find the beginning of sex-reproduction in its simplest form; and to understand what the simplest form would be, the nature of sex-reproduction must be defined. It consists in the mingling of the contents of two cells to form a new one. This new cell is the progeny, and develops more or less directly into the structure of the parents.

Applying this definition to some one-celled form as Protococcus, the simplest possible method of sex-reproduction would be for two cells to come in contact and mutually discharge their contents into a blended mass which becomes a new cell and presently resembles the parents. Such is the beginning of sex-reproduction as we find it in the second group of plants; but it will be noticed that there is no distinction of sex. Both cells are constructed alike and act alike; neither is receptive, for the new cell is constructed upon neutral ground. Sexuality has been attained, but not bisexuality. For this reason, the second plant group is frequently called the "Unisexual Group"; or, from the fact that the cells are for a time yoked together, they are technically called Zygophytes, or "Yoked Plants." In this group, not only is sexuality begun, but bisexuality is hinted at. Plant bodies now begin to consist, not of single cells, but of cell-groups, usually arranged in a chain, forming filiform or thread-like plant bodies. In these filaments or chains of cells, any cell (for they are all alike) can become a reproductive cell and join issues with any other cell, either in the same filament or in another. There is no setting apart of special cells to do this special work, for it is done equally well by all, and all are ordinary vegetative cells. The first hint at bisexuality comes with the fact, that one of these conjugating cells becomes receptive, receiving the contents of the other, and within it the spore or progeny cell is formed.

Such is the case in the common Spirogyras, or "frog-spittles." Although one cell becomes receptive, there is no difference in form nor in contents, and it seems immaterial which becomes the receptive one. In other forms, the development of the spore within the receptive cell demands more or less change of form, thus making a cell differing in appearance from the ordinary ones. To sum up the general phases of this advance in the second group, or Zygophytes; sexuality is attained, at first with no distinction of sex; then one cell becomes receptive, but differs in no respect from any other in form or contents; and finally, the receptive cell becomes more or less changed in form by the development of the spore.

In the third group we would expect to find bisexuality distinctly worked out, but of the simplest kind. The simplest kind of distinct bisexuality would consist in setting apart two cells for the special performance of this function, differing from the ordinary cells of the plant body and from each other in form and contents. Naturally the receptive or female cell, in which the spore is to develop, would be the larger, probably the largest cell produced by the plant. Such is the average condition of sexuality in the third group, called Oöphytes, or "egg-spore plants," in reference to their large spores. It is to be noticed that these male and female cells differ in form and function only from the ordinary cells of the plant body; they are not favored and cared for by any sort of protection. At this point we are confronted by a phase that needs explanation. The life-history of every plant may be considered a cycle, from the spore which produced it round to the spore which it produces. The cycle is traveled continuously without cessation, except at some one point, which is known as the "resting stage." Every plant, in the life cycle referred to, must, at some point, pass through a resting stage, in which condition the plant activities lie dormant, as if to gather strength for the rest of the journey. This stage must always be a protected one, protection which not only shuts out adverse external conditions at a time of low vitality, but prevents response to favorable ones until after a certain lapse of time. In the groups already considered, this resting stage occurs at the spore phase. The protection provided is simply a thick heavy wall about the spore itself; and in this condition the plant exists for a time and then runs its cycle, round through parent form to spore again. To pass through the resting stage at the spore phase is characteristic of a low type. In the third group the resting stage is pushed gradually forward, until the sex-spore becomes, not a rather permanent phase, but simply one of the transient phases, the resting stage occurring after the spore has developed subsequent structures.

The next phase in the sex-reproduction, the one naturally expected in the fourth group, is the protection of the male and female cells or organs. Set apart heretofore in form and function, they are not protected; but in the fourth group this is gradually and at length very completely provided for, as indicated by the group name, Carpophytes, or "plants with spore cases." In certain members of the group—those which look towards Oöphytes—the male and female cells are at first as naked as in Oöphytes, and if the spore passed into the resting stage the plants would belong to that group; but the spore, as soon as formed, proceeds to develop other structures, and, along with the female cell in which it is contained, develops a complex structure called a spore-case, and this is the resting stage.

Summing up the advance made in the fourth group, we find male and female cells distinct in form; the latter finally protected; and the sex-spore ceasing to be the resting stage, and becoming an evanescent phase which passes directly into a complicated structure, which itself is the resting stage. Subsequently, from this complicated structure, or "spore-case," forms like the parent plant are produced by means of so-called spores, not formed by sex-union, but by ordinary cell division, and for that reason called asexual spores. They are simply reproductive bodies cut off from the parent stock, and are chiefly for the dissemination of the plant, no more a product of the sex act than the buds used in grafting or the "slips" in transplanting; but they are the "spores" commonly spoken of among cryptogams, and their name is legion. The essential difference between sexual and asexual spores cannot be too strongly pointed out, for they have led to endless confusion of ideas. Note now the relation of things in this fourth group. The sex-spore produces the structure called the spore-case, which in turn produces asexual spores by ordinary cell division, which in turn reproduces the original parent. In this group, therefore, in the effort to protect the progeny the resting stage was pushed forward, and that condition of things known as "alternation of generations" originated. As a result, we have in a single life-cycle two plant phases, each producing spores, but in a very different way. One phase bears the sex-organs and produces the sex-spore, and hence is called "the sex-plant;" the other is produced by the sex-spore, bears no sex-organs, produces asexual spores, and hence is called "the asexual-plant." The asexual spores produce the sex-plant again, and so the cycle is completed. The idea of protecting the sex-organs or their progeny, begun in the fourth group, becomes more and more fully developed in the groups above. After the covering to the female-cell is established there remains a neck-like passage-way. This passage-way becomes more elongated, and more or less guarded, until in the highest group it too is completely blocked up by loose cellular tissue, which must be penetrated by what is called the "pollen-tube."

To summarize at this point: we have an asexual group as the lowest; then a unisexual group; then a bisexual one; bisexuality appearing as the goal in the first three groups. In the fourth appears the idea of protection, which gradually becomes more and more perfected in method, until, without any sensible break in the series, we reach completest protection in the seventh group, or Phanerogams. Also in the fourth group, after bisexuality had been attained, we find alternate generation, and it is in the development of that character that we find the most striking line of advance from the fourth group to the seventh. Keep in mind that the same road is also completely graded and bridged by way of "protection," as has been already referred to. Given, then, as our starting-point (1) a sex-plant which carries sex-organs and produces a sex-spore; and (2) a resulting asexual plant which produces asexual spores; and remembering that the two are but arcs of the same circle and alternately produce each other, what is the next complication that indicates advance?

The next step, besides the completer protection already referred to, is the completer setting apart of the two phases, so as to make them in structure what they are in function, distinct plants. In members of the fifth group, mosses for instance, we find this to be the case. The ordinary moss-plant, which bears the sex-organs, is, of course, the sex-phase; and borne upon it, though as organically distinct as if it grew upon any other mechanical support, we find the structure which develops from the sex-spore, the so-called "fruit," or spore-case. This is the asexual phase, and produces within itself asexual spores (the only spores meant in the ordinary description of mosses). These spores, in turn, produce the sex-phase, or ordinary moss-plant, and the cycle is complete. There is here a distinct setting apart in function, and, as usually follows, in form also. To the one phase is assigned sex-reproduction; to the other the dissemination of the plant by asexual spores. The ordinary vegetative structures, representing root, stem, and leaves in the higher groups, are here included in the sex-phase also; so this phase is the prominent one, the one ordinarily observed and spoken of as "the plant;" while the asexual phase is more inconspicuous, and, being mechanically borne on the other, seems to be but a part of it.

From this point on, the tendency is to confine the sex-phase more and more entirely to the business of sex-reproduction, and to transfer the vegetative structures more and more completely to the asexual phase. The result is, that as we advance towards the higher groups the sex-phase becomes less and less prominent, as the function is taken away from it which involves size and display; while the asexual phase, taking on the function involving display, becomes more and more prominent, and is popularly styled "the plant." So that, while "the plant" in the case of mosses is the sexual phase in the life-cycle, "the plant" in higher groups is very probably the asexual phase, representing the so-called "fruit" of the moss. As the sex-phase is to be more and more confined to sex-reproduction, it can easily be understood how it can be reduced more and more, until it has only the cells actually needed; and these cells may be reduced to two, one to represent the plant, and the other the sex-organ growing upon it. This seems to represent the goal set before the sex-phase, when in the sixth group the vegetative structures begin to leave it. From this point on evolution reduces and simplifies the sex-phase, increases and makes more and more complex the asexual phase. The sex-phase thus begins simply in the lowest groups and ends simply in the highest, reaching in the fifth probably its greatest complexity. While this is true of the structure of the sex-phase, it is not true of the sex-function, for the very highest possible degree of differentiation in this regard is attained in the highest group.

In the sixth group, represented by ferns and their allies, we find a very wide distinction between the sexual and asexual phases; the latter having become very prominent and having possessed itself of most of the vegetative structures, being the ordinary fern-plant, with its great display of vegetative structures and asexual spores, but no sex-organs. Linnæus may well have examined the fern in vain for any evidence of sex-organs, for he only knew of this prominent asexual phase, and in his despair consigned the group to "Cryptogams," "hidden sexuality." The asexual spores (borne, you may remember, upon the leaf-structures of the fern) develop, of course, into the sex-phase; but that is so small and hidden among the mold in which the spore has fallen, that it may well escape observation. It is simply a minute flat disk-like body, with vegetative cells and root-like processes enough to make it able to live long enough to accomplish its function of sex-reproduction. But it bears the sex-organs, produces the sex-spore, and from it there arises the beautiful or stately asexual plant. The reduction of the sex-phase could go no further than this, and at the same time compel it to make its own living from soil and air. If any more reduction be made, the sex-phase cannot be organically separated from the other, but must depend upon it for elaborated food.

By this means the utmost possible reduction could be reached, and we must expect this to be the next step in advance. For instance, the asexual spores of the fern are scattered over the soil. From them springs the reduced sex-phase, known as the prothallium, and capable of independent existence. Any further reduction, which would make it incapable of independent existence, would necessitate that the asexual spore be not separated from the asexual plant, but developed into the prothallium upon it so as to receive elaborated nourishment. The reason why a prothallium cannot be indefinitely reduced, and still retain the power of independent existence, is not far to seek. It is on the same principle that a small battery cannot work an indefinite amount of wire. The formation of high-grade reproductive cells is an exhaustive work, and it would require more than a few cells to manufacture such an amount of highly organized substance from crude material. Hence we reach a point, beyond which it would be a physical impossibility to reduce the prothallium, without arranging to supply it with material already highly organized.

Remembering, then, that from the sixth group, represented by ferns, higher rank is to be marked by a reduction of the sex-phase or prothallium, which finally cannot be separated from the asexual plant, let us note a new phase of differentiation which begins to be prominent in the upper members of the sixth group, and continues as the highest expression of differentiation in the seventh and last. Although vegetative organs have departed from the sex-phase, there still remains a double function, namely, the production of male and female cells or organs. It seems to be a law, that so long as anything remains to be differentiated, differentiation will continue; and the separation of the sex-organs is its next possible expression. Instead, therefore, of having a single prothallium bearing both male and female organs, we find two prothallia; one male and the other female. This state of things is reached by one set of organs first becoming functionless, and finally being suppressed. Remembering that these prothallia are developed from asexual spores, it does not seem strange that this diœcism extends presently to these spores themselves, and that we soon find what may be styled (from the nature of their product) male and female asexual spores. This brings us to the heterosporous arrangement, a feature which continues to the last, and which must be considered a high-rank character, possessed only by the higher members of the sixth group, and by the seventh; and yet, through the very midst of this condition of things, accompanied as it is by many intergrading characters in all the other plant structures, the old abyss between Cryptogams and Phanerogams was supposed to run. To sum up the lines of advance, with which we enter the group Phanerogams, we find male and female spores, producing male and female prothallia, and those prothallia so much reduced that not only do they not become separated from the asexual plant, but are developed within the asexual spore itself. But these same important characters are to be found among the highest Cryptogams, and we must conclude that any line of separation is one of our own drawing, and has no representation in nature.

It remains to apply to the well-known parts of any flowering plant the terminology that we have been using in outlining the evolution of the sex-apparatus. The asexual phase, or part of the cycle, is "the plant" with its rich display of vegetative organs, consisting of root, stem, leaves, and their various modifications. This asexual phase produces asexual spores of two kinds, called male and female, because they are to produce male and female prothallia. It would be an interesting line of development to note the gradual differentiation of the apparatus for making these asexual spores, but that is aside from our purpose. The final result is, that in the flowering plant we are considering, highly specialized sets of organs produce the two kinds of asexual spores, which have been called pollen-grains and embryo-sacs. It seems strange to be forced to give up pollen-grains or embryo-sacs as sexual affairs, for in our old notion of things they represented the very essence of sex; but the fact remains that they are asexual spores and simply give rise to prothallia which bear the sex-organs and give rise to the sex-spore.

The two prothallia which are developed from these asexual spores have reached the highest degree of reduction, developing within the spores themselves. In the case of the pollen-spore two or more cells are developed, which may be easily seen by the use of the proper reagents, and this small group represents the male prothallium, one of the sex-phases in the life cycle. This much reduced plant sets apart one or more of its cells to do vegetative or growth work, and another to be the male organ. A very vigorous growth of this prothallium is demanded in the development of the pollen-tube, through which the male cell discharges its contents. This pollen-tube does not usually find an open passage-way, but one that is blocked up with spongy tissue, called "conductive tissue," through which it makes way like a parasite invading the tissues of a host plant.

In the case of the embryo-sac, the female asexual spore, the development of the prothallium is still feebler, the cells representing it not only being few in number, but free from each other,—a sort of disorganized tissue. The cells representing the female organs are clustered near the apex of the embryo-sac, forming what we now call the "egg-apparatus," while those that probably represent the vegetative cells of the prothallium are clustered at the other end of the embryo-sac, and are styled "antipodal cells." In pines, representing the lowest group of flowering plants, the female prothallium is a very distinct and compact tissue, bearing regulation female organs, the so-called "corpuscula." This but shows their position upon the lower border line of Phanerogams. The sex-phase in the life cycle, therefore, which in mosses stood for the whole plant as we ordinarily recognize it, in Phanerogams has become reduced to little clusters of cells developed within the pollen-spore and embryo-sac, so inconspicuous that it has remained for the modern reagents to discover their existence. The real sex-spore, or oöspore of Phanerogams, is the single fertilized cell in the embryo-sac, which at once develops into the embryo, at which point Phanerogams pass into the resting stage, in this group called "the seed." The sex-spore, since the fourth group, has become such an evanescent thing, so out of reach of common observation, that very naturally it has been the common opinion that the comparatively permanent asexual spores are sex affairs. Sex-spores are directly formed by sex-union; while pollen-grains and embryo-sacs are never formed in any such way. Thus have I hastily traced one of the principal threads upon which our botanical facts are strung. And as one examines the subject in more of its details, he becomes irresistibly impressed with the idea that here is a great scheme of development, directed by laws of which we are beginning to catch glimpses, and by which the whole fabric of a great kingdom has been beautifully and continuously worked out.

RECENT LITERATURE.

The Geological History of Plants. By Sir J. William Dawson, C.M.G., LL.D., F.R.S., etc. International Scientific Series. New York, 1888.—This book is a striking example of the truth that scientific specialists cannot be induced to say much about things which they have not themselves carefully studied. Purporting to treat a great department of palæontology from a cosmopolitan standpoint, it is really a summary of the author's own extensive researches within the British American Provinces, enriched by much comparative matter drawn from similar phenomena in other lands. What is therefore lost in generality is gained in thoroughness and reliability. There is no branch of science that stands more in need of summarizing and systemizing than that of palæobotany, and every book that successfully attempts this should be warmly welcomed. With the above qualification this work does this, and it is therefore a valuable contribution to the thus far scattered and desultory literature of the subject. Taking up the several geological formations in their ascending order, the characteristic vegetation of each is ably portrayed by the author, though with an unevenness of treatment corresponding to the imperfection of the geological record in the region to which he has devoted his life. The vegetable origin of the Laurentian graphite is defended with great force, and the existence of a primordial flora contemporaneous with *Eozoon canadense* is maintained. Most of the alleged